Aeropower Thrust Area

- System design of fuel cell enabled concepts (GT)
- High power density solid-oxide fuel cells (GT)
- High efficiency superconducting electric motors (FAMU)
- Integrated power network management (FAMU)

Automotive Example: GM AUTOnomy Concept

"Fuel cells will power cars with little or no waste at all. We happen to believe that fuel cell cars are the wave of the future; that fuel cells offer incredible opportunity."

President George W. Bush, February 25, 2002.

2.5 Advanced Power Technology

2.5.1 Micro-structured Solid Oxide Fuel Cells for Aerospace Power Generation

David Parekh, Meilin Liu, Comas Haynes, Georgia Tech

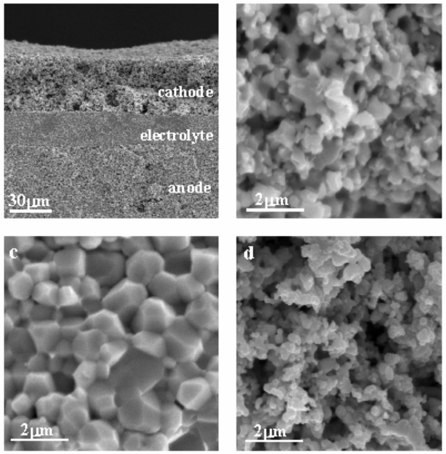
Science & Technology Objective(s):

- Functionally graded electrodes for high power density
- Sulfur tolerant anodes suitable for use with jet fuels
- Modeling of steady and transient processes
- Solid oxide fuel cells for aircraft propulsion & APUs

Collaborations:

- Government - DOE, DARPA, NSF, ONR, ARO
- URETI - GT System Design & FAMU Power Network
- Industry - UTC Fuel Cells, Siemens, Delphi, Boeing
- Synergism with existing programs - DOE Solid-State Energy Conversion Alliance, DARPA Palm Power

Microstructured materials enhance power density



Proposed Approach:

- Development of new microstructured materials for high power density and sulfur tolerance
- Lagrangian modeling of electrochemical and thermodynamic processes
- System modeling and integration into demonstrator

NASA Relevance/Impact:

- Zero CO_2 emission, low-noise propulsion & power source
- Increased safety through distributed power
- All-electric, non-polluting civilian VSTOL transport

Milestones/Accomplishments:

- Quantify requirements for power sources on current and future aircraft based on system studies
- Development of new materials specifically engineered to provide high power density required for flight applications
- Integrated power subsystem including fuel cell and superconducting motors
- Flight demonstration of unmanned, all-electric air vehicle powered by high power density solid oxide fuel cells

Georgia Institute of Technology · The Ohio State University · FAMU Florida A&M University · CWRU

2.5.1 Proposed Approach

- SYSTEM ANALYSIS: Determine baseline requirements for propulsion and electrical power based on system analysis of revolutionary aircraft concepts.
- MATERIALS: Fabrication of electrodes and SOFCs using combustion CVD and microfabrication; characterization of fuel cell reactions using in-situ FTIR/Raman, impedance, and MS/GC measurements.
- MODELING: Mathematical modeling of functionally graded electrodes; Lagrangian electrochemical analysis of cell performance under steady and transient loads; first-order modeling of complete system including fuel processor, fuel cell stack, and power electronics.
- INTEGRATION: Develop fuel cell module ideally suited for power and weight constraints of flight application and characteristics of electrical architecture and loads.
- DEMONSTRATION: Design, develop, and fly subscale, unmanned prototype of fuel-cell powered aircraft utilizing high-density solid oxide fuel cells and unique electrical architecture and motors from Tasks 2.1.2 and 2.1.3.

2.5 Advanced Aeropower Technology

2.5.2 Integrated Power Management

Thomas Baldwin & Cesar Luongo, FAMU

Science & Technology Objective(s):

- Examine the impact of distributed generation, automatic reconfiguration, power electronics, and super-conductivity on aircraft power systems
- Provide simulation capabilities to examine the performance of individual components and control strategies.

Collaborations:

- Government - ONR, NASA LaRC (SAB)
- URETI - GT (ASDL), GTRI (Parekh)
- Industry – RTDS
- Synergism with existing programs – Navy All Electric Ship Program

Proposed Approach:

- Examine alternative system configurations using real-time digital simulation coupled with hardware-in-the-loop modeling.
- Examine techniques for automatic system reconfiguration in response to failure or damage.
- Analyze the impact of superconducting and power electronic devices on power system performance.

NASA Relevance/Impact:

- Increased reliability, safety and performance through improved redundancy and system reconfiguration
- Provide a test platform for testing new concepts and technologies in power distribution and controls

Real-time simulation of a power network

Milestones/Accomplishments:

- Model a base-line electric power system for the aircraft on the real-time digital simulator.
- Complete simulation studies of system reconfiguration and power distribution controls.
- Assessment of the impact of distributed generation and superconductivity on aircraft power systems.

2.5.2 Proposed Approach

- Examine alternative system configurations using real-time digital simulation (RTDS)
  - model a base-line electric power system for the specified aircraft on the real-time digital simulator
  - creating alternative designs of the power system and perform a comparison analysis (i.e. distributed generation and energy storage)
- Examine techniques for automatic system reconfiguration
  - model the automatic system reconfiguration and power controls on the RTDS simulator
  - simulate failures and damage to the aircraft power system and analyze the system responses and ability to restore power to critical flight systems
- Analyze the impact of new devices and technologies on performance
  - develop and insert RTDS simulator models for new technologies (i.e. super-conducting and power electronics devices)
  - perform a comparison analysis of the new technologies, including impact on weight and size as well as power distribution performance and control

2.5 Advanced Aeropower Technology
2.5.3 High Efficiency Superconducting Electric Motor

Cesar Luongo, FAMU

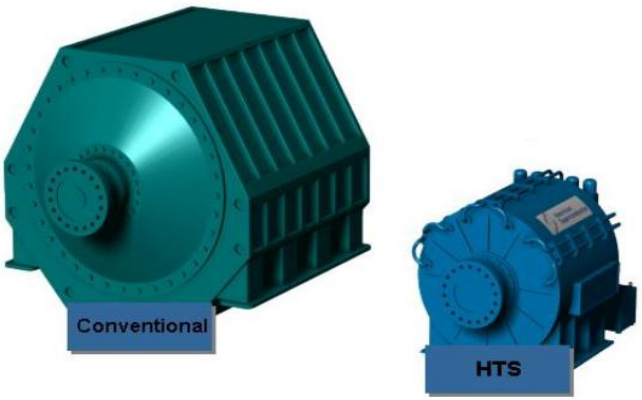
Science & Technology Objective(s):
- Establish targets for aircraft-based s/c motors
- Develop s/c motor concepts to reach targets
- Integrate to other technologies for new concepts of all-electric aircraft

Collaborations:
- Government - NASA GRC (ASAO), LaRC (SAB)
- URETI - GT (ASDL)
- Industry - American Superconductor, Boeing
- Synergism with existing programs - ONR all-electric ship (CAPS)

Proposed Approach:
- Benchmark existing conventional and s/c motors
- Develop conceptual design of high power density s/c motor
- Integrate to all-electric aircraft concept

NASA Relevance/Impact:
- Low weight/volume electric motors
- Increased use of electrical actuators, elimination of mechanical/hydraulic systems
- All-electric, non-polluting civilian transports

Space and weight reduction using superconductors



Milestones/Accomplishments:
- Establish targets for material characteristics and s/c motor performance for air-worthiness, determine relevant ratings (9/2003)
- Development of a baseline design for s/c motor meeting air-worthiness targets for rating and performance (9/2005)
- Integrate design to an all-electric transport concept and to new architectures for aircraft power systems (based on fuel cell generation). Define and initiate a program to build a relevant prototype (9/2007)

2.5.3 Proposed Approach

- Develop database of relevant material properties (superconductor, insulation, cryogenic, etc.) for the design of high-performance s/c motors
- Establish power rating targets for aircraft-relevant motors. Develop performance targets for s/c motor (power density, weight, etc.)
- Develop motor concepts capable of attaining targets. Perform trade-off to select most promising concept. Proceed with a detailed design of the s/c motor based on the preferred concept
- Integrate findings from this task to subtasks on electrical network architecture (2.5.2) and SO fuel cell studies (2.5.1), as well as overall system integration tasks (2.1.1 and 2.1.2)
- Determine best path for a prototype development program (sub-scale or full-scale), establish goals, schedule, and budget, and proceed with hardware demonstration program as resources allow